



# Nitrate in Groundwater

Ion Exchange and Catalyst Water Treatment  
Solutions

Calgon Carbon Corporation  
Nitrate Treatment Technology Workshop

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# Learning Objectives

- Nitrate
  - Source
  - Health Concerns and Standards
- Treatment Technologies Options
  - What is Ion Exchange
  - What is a Catalyst Treatment System

Cost Analysis

# Nitrate Source

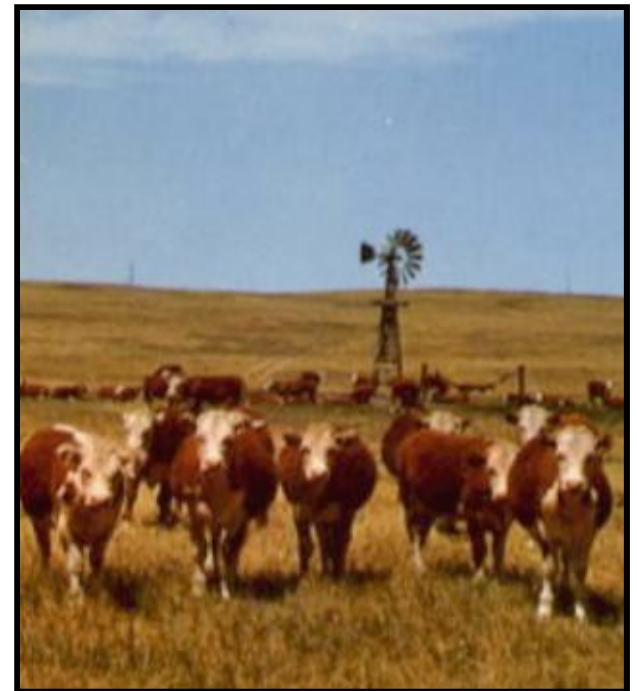
- A naturally occurring compound formed when nitrogen and oxygen combine. Small amounts are not a problem. Excess amounts pollute
- Often a “rural” problem - originates with fertilizer use, livestock waste, septic fields
- Some industrial sources and transportation exhaust sources
- Throughout US



# Nitrate:

## Health Concerns

- Interferes with the blood's ability to transport oxygen
- Particularly at risk are babies younger than six months and nursing mothers
- Can lead to “Blue Baby Syndrome”. Unconfirmed links to cancer and diabetes.
- The United States drinking water standard is 10 ppm as N, or 44 ppm as  $\text{NO}_3$



# Treatment Technology Options

## Three Basic Options

- Ion Exchange
  - Most Common for nitrate and low levels of perchlorate
- Biological
  - Works well with high levels of perchlorate and nitrates
  - Large footprint
- Membrane / Reverse Osmosis / Ultrafiltration
  - High waste up to to 20% of treatment stream and energy use

# What is Ion Exchange?

- Ion exchange uses resins which are synthetic polymers
- Ion exchange resins are primarily designed to remove ions from a dilute solution, and concentrate the removed ions into a relatively small volume
- Ion exchange resins are able to exchange their cations (or anions) for other cations (or anions)
- Both  $\text{NO}_3$  and  $\text{ClO}_4$  are anions

# What is Ion Exchange?

- A typical service cycle of a resin bed starts with an exchange or adsorption of the  $\text{NO}_3$  and or  $\text{ClO}_4$  to be removed from the feed stream
- Service cycle of regenerable IX system for  $\text{NO}_3$  systems last only hours due to high loading of  $\text{NO}_3$
- Regenerable IX: Once the useful bed capacity is exhausted, the exchange process is reversed by a chemical regeneration of salt, the bed is then rinsed to remove the excess chemical, and then the bed is returned to service
- The salt is a waste that will need to be disposed

# Ion Exchange Treatment

- Regenerable Ion Exchange  $\text{NO}_3$ 
  - ISEP (Continuous IX Contactor with Salt Regeneration)
    - non specific ix resins, onsite regeneration
  - Fixed Bed (Batch IX Contactor with Salt Regeneration)
    - non specific ix resins, onsite regeneration
- Regenerable Ion Exchange  $\text{NO}_3$ ,  $\text{ClO}_4$ ,  $\text{Cr}(\text{vi})$ , etc
  - ISEP Continuous IX Contactor with Salt Regeneration



# Regenerable Ion Exchange for $\text{NO}_3$ Removal

(always regenerable due to high concentrations of  $\text{NO}_3$ )

- ISEP (Ion Separator)
  - Moving bed
  - Less moving parts, mechanical distributor directs streams for adsorption, rinse and regeneration
  - Lower waste
  - Removes other anions such as Arsenic,  $\text{Cr}(\text{vi})$ ,  $\text{ClO}_4$ , Uranium in addition to  $\text{NO}_3$
  - Consistent water quality
- Fixed Bed Ion Exchange
  - Utilizes air valves for direction of streams for adsorption, rinse and regeneration
  - Higher waste
  - Water Quality varies during adsorption cycle

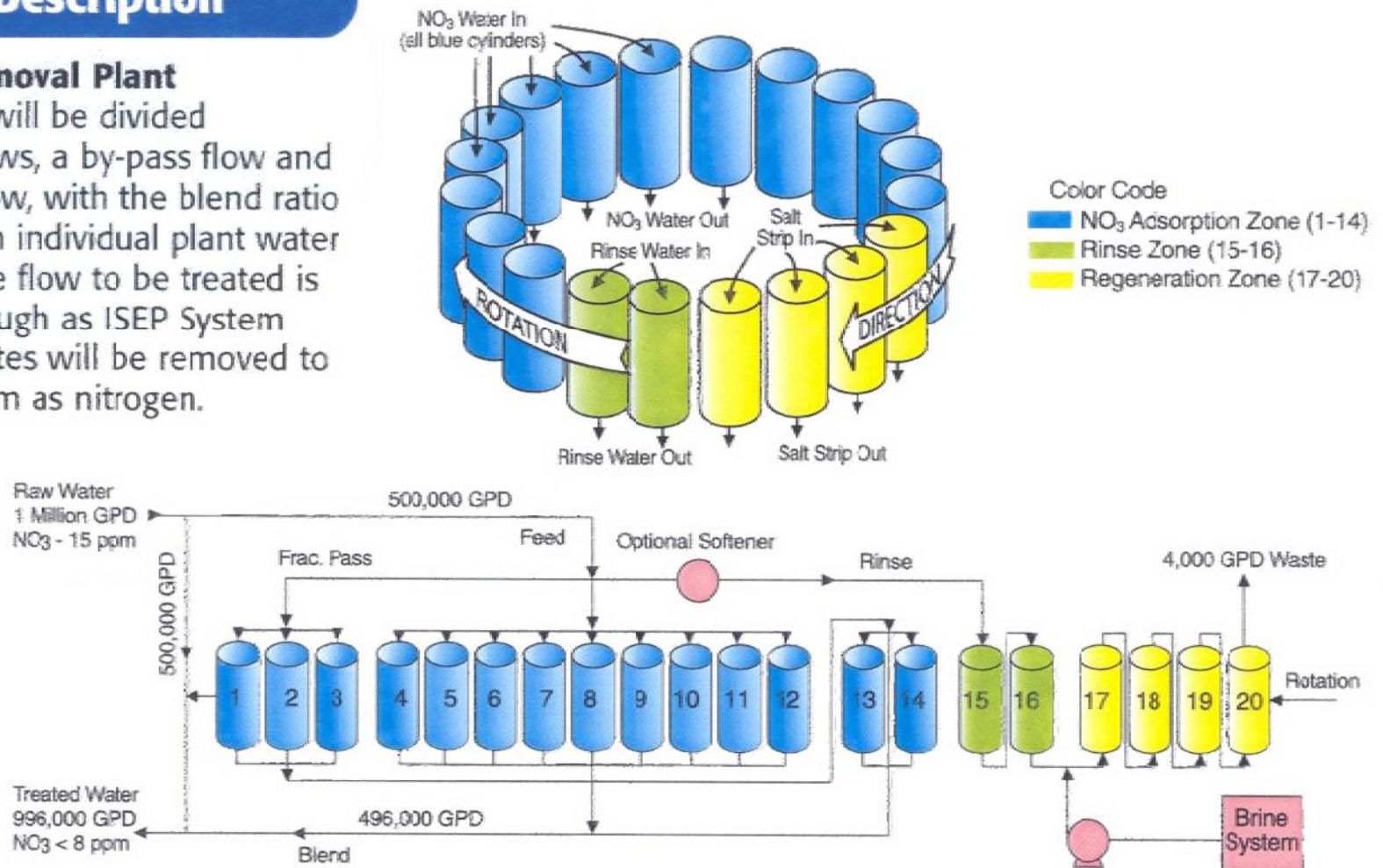
# ISEP Process

## Typical ISEP Process

### Process Description

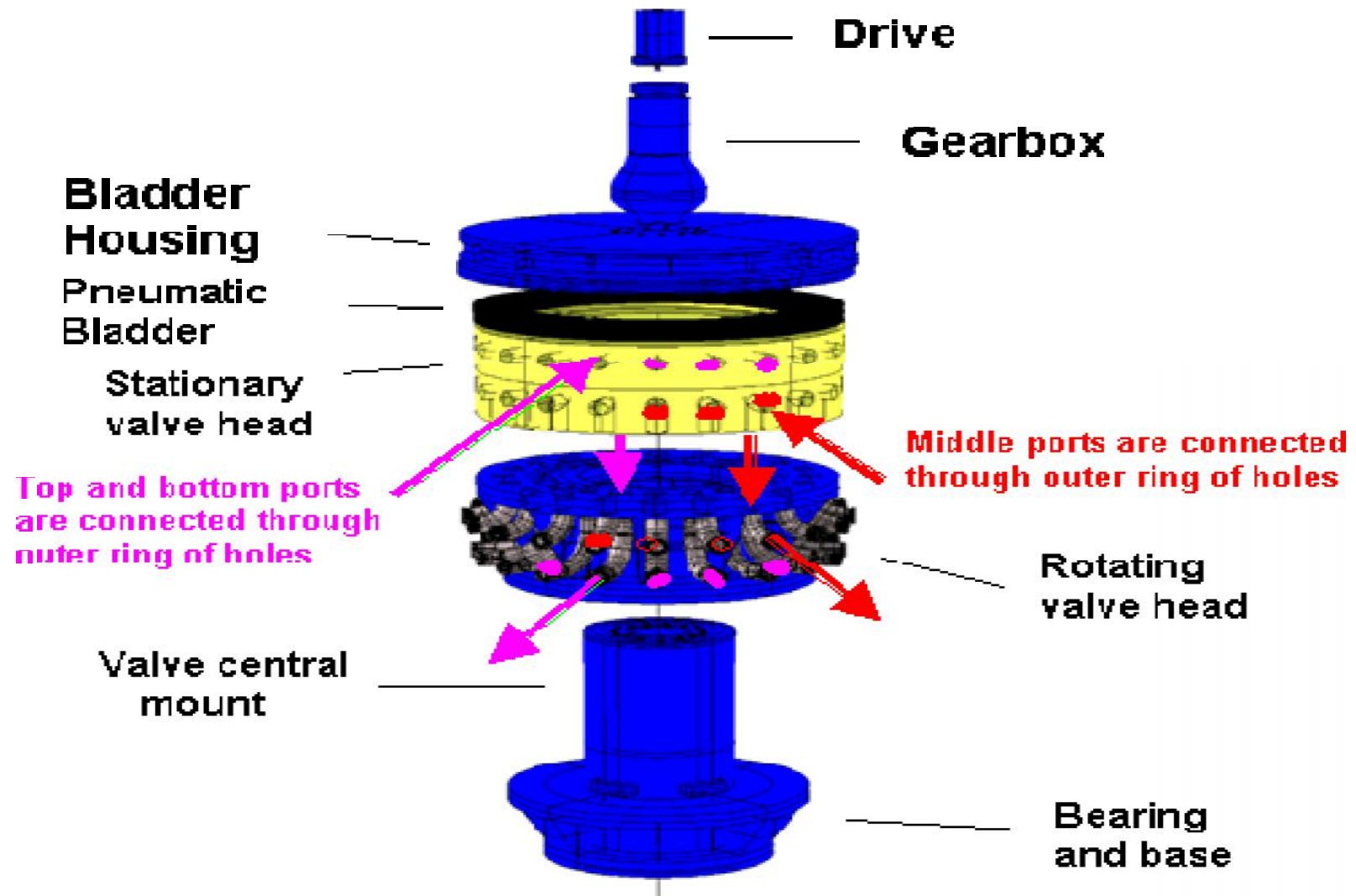
#### Nitrate Removal Plant

Raw water will be divided into two flows, a by-pass flow and a treated flow, with the blend ratio based on an individual plant water analysis. The flow to be treated is passed through as ISEP System where Nitrates will be removed to below 1 ppm as nitrogen.



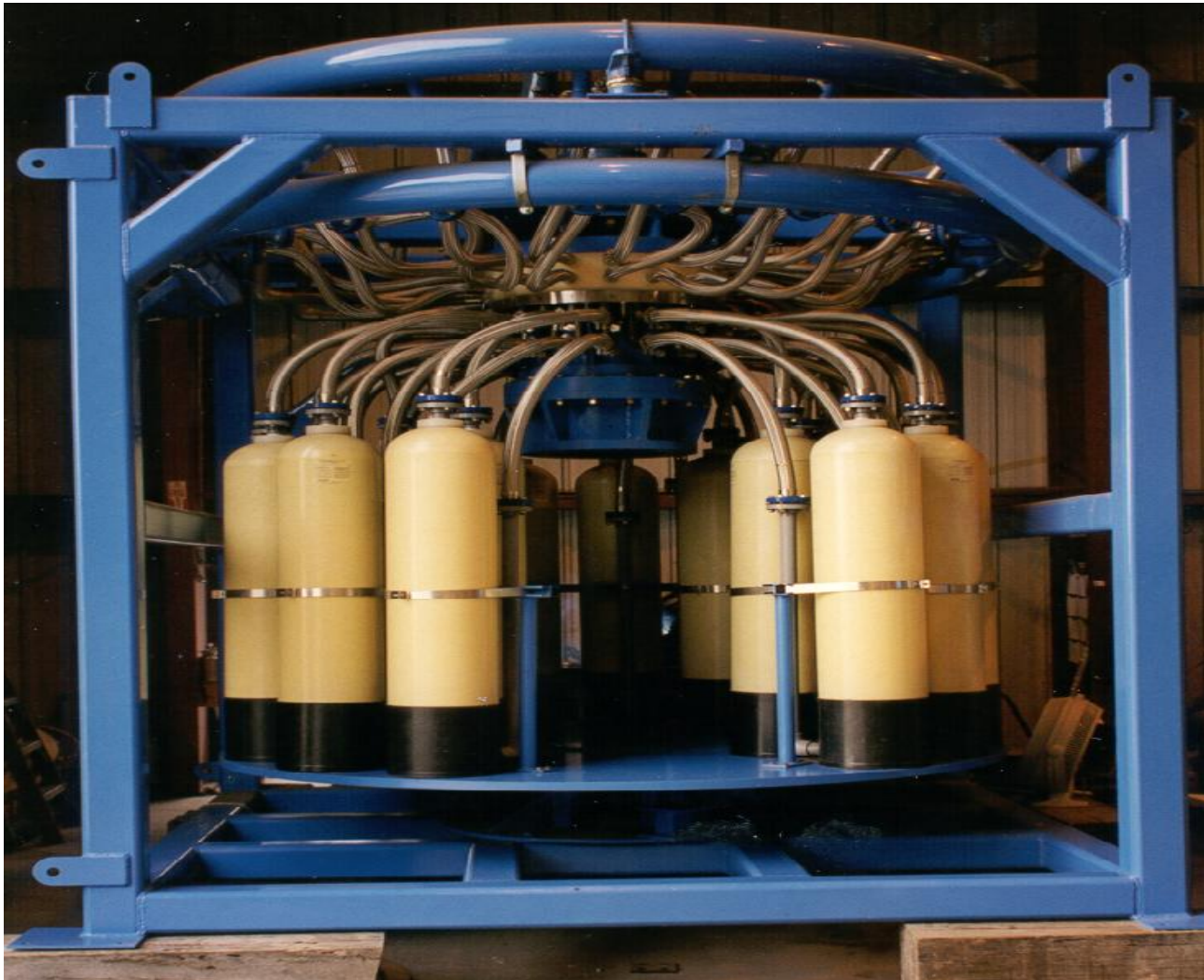
# ISEP/CSEP Process

## Patented Multi-Port Valve





# Typical ISEP System (1000 gpm)



# **Example Project: Southern California (5000 gpm)**

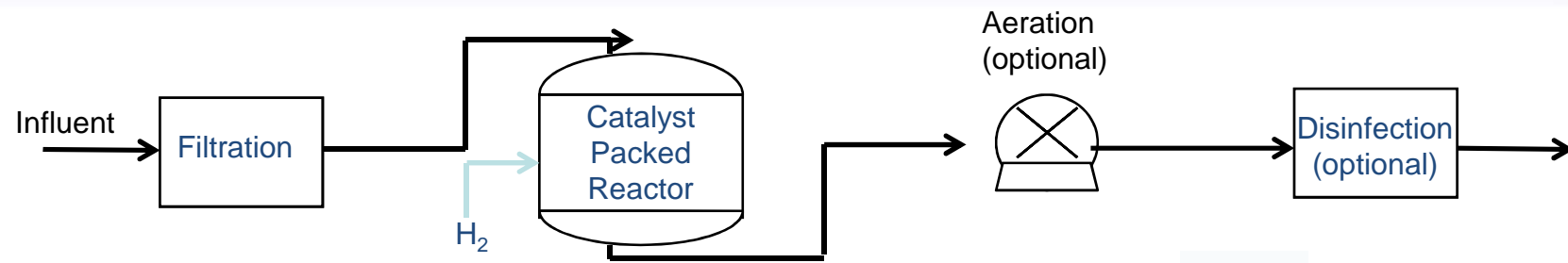
**ISEP Nitrate/Perchlorate Removal System**



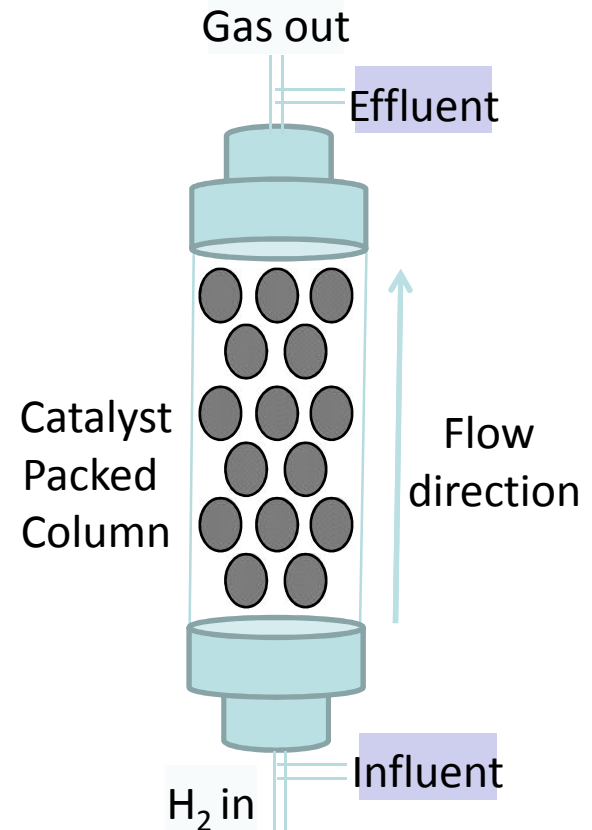
# What is a Catalyst Treatment System

- The Catalyst allows a reaction between the nitrate and hydrogen
- Produces a innocuous end product of nitrogen gas
- Catalyst reaction for this application is at room temperature
- Zero liquid waste
- Developed with University of Illinois

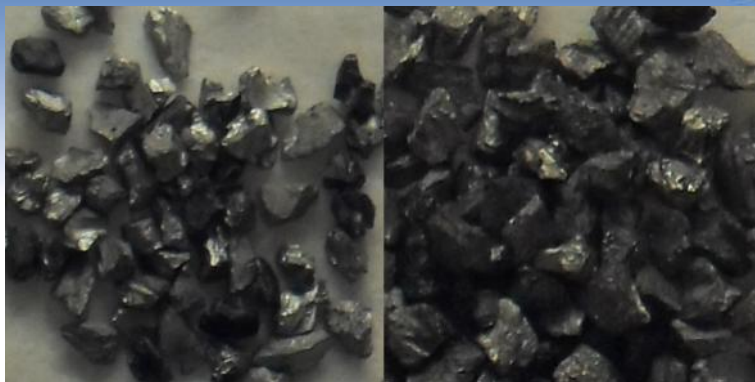
# Schematic of the Treatment System



Close up of the catalyst reactor







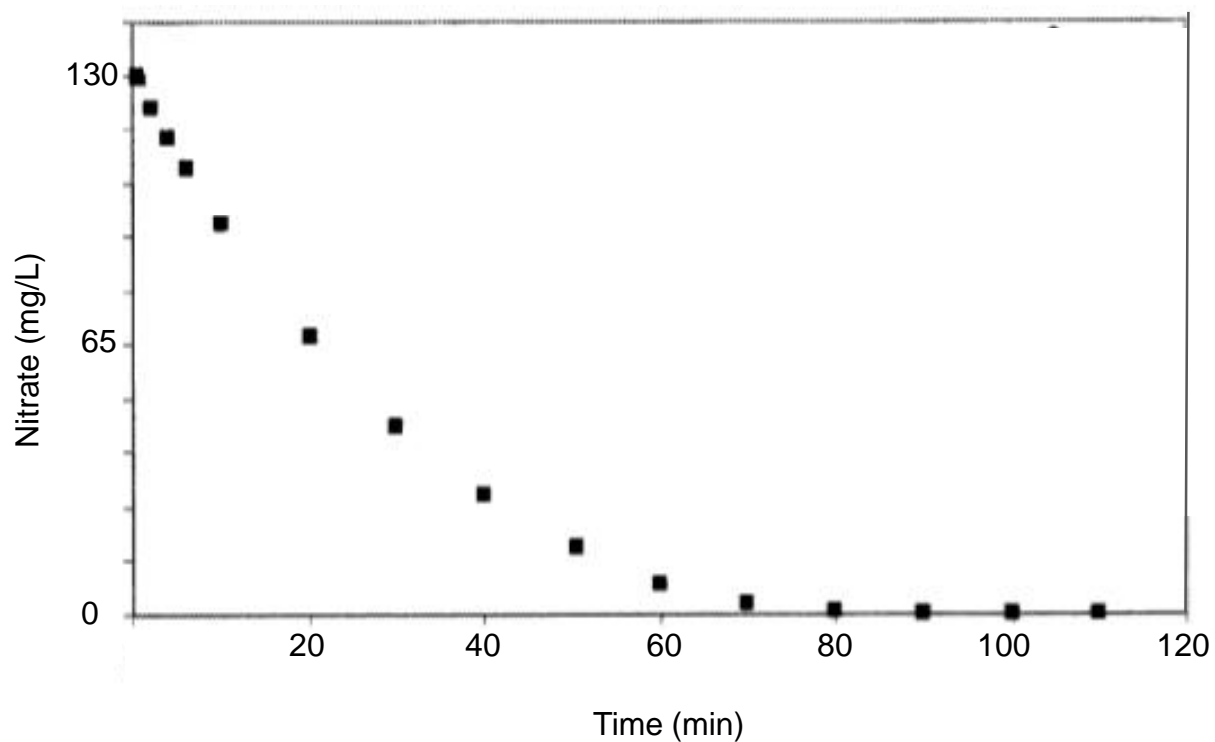
Pd-In on carbon support

### Catalytic activity of different catalysts

catalyst	$k_{\text{obs}}$ (L/ min g cat)
Pd-Cu	0.25
Pd-In*	0.19
Pd-Sn	0.10

\*Combines high activity with good long-term stability

### Nitrate reduction profile





# Reactor Design

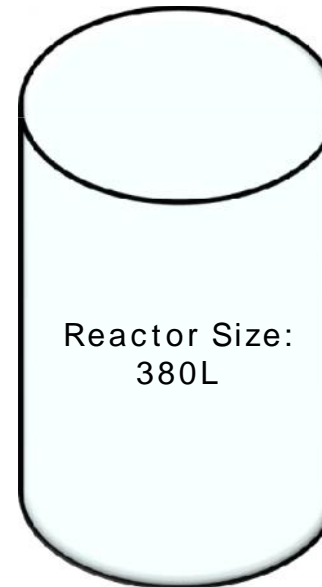
$Q=50 \text{ gpm}$  |  $C_{\text{influent}}=70 \text{ ppm NO}_3^-$  |  $C_{\text{effluent}}=13 \text{ mg/L}$

## Pd-In Catalyst

$k = 0.045 \text{ L/ min g cat}$   
0.5wt%Pd-0.1wt%In

## Design & Cost

Mass Pd	.....	830 g
Mass In	.....	166 g
Total Mass Catalyst	.....	166 kg



# Cost Analysis

- ISEP Costs
  - Flow ranges 50 to 5000 gpm
  - Cost for a 100 gpm system
    - Influent Water Quality
      - Nitrate – 70 ppm as NO<sub>3</sub>
      - Sulfate – 60 ppm
      - Chloride – 20 ppm
    - Treatment Goals
      - Nitrate – 35 ppm as NO<sub>3</sub>

# Cost Analysis

- ISEP Model – TC-0810-120-0.5
  - Capital Costs including Resin
    - \$375,000
  - Installation Cost
    - \$40,000 (units are skid mounted)
  - O&M Costs
    - Salt Usage – 225 lbs/day
    - Waste Generated – <0.2%

# Cost Analysis

- Catalyst Cost Summary
  - Flow range 50 to 500 gpm
  - Cost for a 50 gpm system
  - Capital Costs including Catalyst
    - \$100,000
  - Installation Cost
    - \$10,000 (unit is skid mounted)
  - O&M Costs
    - Hydrogen Usage – 5.1 lbs/day
    - Catalyst Replacement – Every 3-5 years

# Summary

- Nitrates are toxic chemicals that can pose serious risks to human health and the environment
  - The US EPA has regulated Nitrates
- Ion Exchange has been established as a Solution for nitrate removal for over 15 years

# Special Thanks

- Dr Charles Werth University of Illinois, Environmental Engineering
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- Tim Knowlton, Sr. Process Engineer Calgon Carbon



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Thank You for your time.

Questions?

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